CostQuest Associates (CQA)
Economic Research & Analysis

CTIA-The Wireless Association
U.S. Ubiquitous Mobility Study
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Introduction & Summary of Findings

This study, commissioned by CTIA-The Wireless Association® ("CTIA"), provides a snapshot of the state of mobile broadband deployment, presenting detailed information on where mobile broadband services have been deployed today and what it will take to deliver them ubiquitously through the country. Achieving universal coverage of mobile broadband services is essential because, as the FCC's National Broadband Plan accurately observed, "mobile services and technologies are driving innovation and playing an increasingly important role in our lives and our economy."[1] The findings presented here demonstrate the significant investment that will be required to achieve ubiquitous access to mobile broadband services – between 7.8 to 21 billion dollars in initial investment alone, depending on the coverage goal.

The ubiquitous deployment of mobile services provides consumers greater safety, convenience, efficiency, and proximity. Transitioning from narrowband to broadband has brought access to information and services almost unimaginable a short time ago. Clearly it isn't just our individual lives that are benefited by the mobile broadband revolution. The growth of commerce and the economic well-being of the nation are improved with the deployment and adoption of mobile broadband services. To maximize this economic impact all citizens should have the chance to participate. To accomplish this universal access, a key element is to promote ubiquitous wireless coverage and access to the kinds of advanced mobile wireless broadband services that most U.S. consumers now have available to them.

In this study, CostQuest provides a fact-based assessment of the availability of mobile broadband services today. In order to provide a simple and clear analysis, this study focuses on the two types or "groupings" of mobile broadband services that are being predominantly deployed today. First, the study considers mobile broadband services powered by Evolution Data Optimized ("EvDO") and High-Speed Packet Access ("HSPA") technologies. Second, the study analyzes next generation Orthogonal Frequency-Division Multiplexing ("OFDM") mobile broadband services, powered by Long Term Evolution ("LTE") and WiMAX networks. . Collectively, these mobile broadband services provide consumers increasingly robust broadband connectivity to voice, data, and video services. CTIA identified these technologies for investigation because they reflect the primary areas of investment by mobile broadband providers, as they seek to expand the capacity and coverage of their networks. In addition, the findings regarding mobile broadband services powered by EVDO and HSPA technologies provide a useful update to CostQuest's previous *U.S. Ubiquitous Mobility Study*, conducted in 2008.[2]

Deployment of mobile broadband services is happening in the U.S. at a rapid pace, but these technologies are not yet available to all U.S. consumers in all areas of the country, especially those who reside, work, and travel in less dense, rural areas. These areas are typically the most costly in which to deploy, are sparsely populated, and are least likely to be included in early commercial build-out plans. The looming questions then are: "What is meant by ubiquitous mobile broadband coverage? How far do we have to go? And, what is the cost to provide such coverage?" The answer to these questions will have considerable legal and policy implications – especially in the area of universal service.

To frame the concept of ubiquitous wireless and provide cost estimates, CostQuest Associates was commissioned, once again, by CTIA to study wireless coverage in the United States to a) identify both areas

[1] National Broadband Plan at 9.

[2] *See U.S. Ubiquitous Mobility Study*, CostQuest Associates, filed in WC Docket No. 05-337 (Apr. 17, 2008), *available at: http://files.ctia.org/pdf/filings/080417_High_Cost_USF_Reform_Comments_Combined.pdf*

and population not served by mobile broadband technologies, and b) estimate the up-front deployment costs to build mobile broadband networks to unserved and underserved areas.

To conduct the study, CostQuest collected coverage maps. It then compared data to the road network where people live and commute. Utilization of the road network of the United States was done in order to define what is meant ubiquitous coverage. For the country to take advantage of the benefits of mobile broadband – to farmers, and businesses, to hospitals and schools, and to citizens – any analysis of mobile broadband coverage should include an analysis of not only where customers live, but also where they work and transit. Partitioning up the country into cell site size areas, CostQuest was able to estimate the assets that would need to be deployed to achieve such ubiquity.

In defining ubiquity, this study recognizes that, within each grouping of mobile broadband technologies (*i.e.*, either EVDO/HSPA technologies, or LTE/WiMAX technologies), the predominant types of mobile broadband technologies are not interoperable. To address this technological limitation, CostQuest's 2008 study estimated the costs to deploy both EVDO and HSPA technologies throughout the country. Estimating the cost of such "dual" deployments ensures that users (whether consumers, business users, medical professionals, or even in some cases public safety officials) using one technology would be able to access mobile broadband services – and even mobile voice services – wherever they work or travel.

This study follows a similar approach in the first of three scenarios presented here, estimating the cost to fund dual deployments of EVDO and HSPA mobile broadband services. In the second scenario, this study estimates the cost to fund dual deployments of next generation OFDM mobile broadband services (*i.e.*, both LTE and WiMAX). Finally, in the third scenario, this study also includes an estimate of the costs to deploy a "single" next generation OFDM technology across the country (*i.e.*, either LTE or WiMAX, depending on which would require the least investment in a given area).

It is important to note that this study does not seek to estimate the substantial costs related to *maintaining* a mobile broadband network or *providing* mobile wireless voice, data, and, increasingly, video *services* on an on-going basis. Such operations and maintenance costs must be accounted for by mobile broadband providers when they determine whether an area can be economically served on an ongoing basis and by policymakers, as they formulate policy choices.[3]

[3] The report also does not assess the cost of extending basic wireless voice networks.

Below is a summary of the key findings of this study.

Summary of Findings

Next Generation OFDM Mobile Broadband Services

(LTE and WiMAX Technologies)

1) Approximately **165 Million U.S. residents** currently do not have access to any form of next generation OFDM mobile broadband service (LTE or WiMAX) at their primary place of residence. About **225 Million** do not have access to both technologies of next generation OFDM mobile broadband.

2) We estimate that approximately **90% of road miles** in the United States do not have access to any form of next generation OFDM mobile broadband services. Approximately 95% of road miles do not have access to both technologies of next generation OFDM mobile broadband.

3) The estimated minimum investment needed to build out infrastructure to facilitate the two technologies of next generation OFDM mobile broadband service ubiquitously is approximately **$21 billion**. The estimated minimum investment needed to build out infrastructure to facilitate only one next generation OFDM technology is approximately **$10 billion**.

4) Study estimates initial deployment cost only. Cost of maintenance and service provision additional.

Mobile Broadband Services via EVDO and HSPA Technologies

1) Approximately **54 Million U.S. residents** currently do not have full access to mobile broadband service via both EVDO and HSPA technologies at their primary place of residence.

2) We estimate that approximately **62% of road miles** in the United States do not have full access to both EVDO and HSPA mobile broadband services.

3) The estimated minimum investment needed to build out infrastructure to facilitate full access to these EVDO and HSPA mobile broadband service ubiquitously is approximately **$7.8 billion**.

4) Study estimates initial deployment cost only. Cost of maintenance and service provision additional.

Methodology Fundamentals

The purpose of this study is to frame a complicated factual question that underlies important policy debates. This question is: what upfront investment is necessary to augment the existing wireless infrastructure to provide ubiquitous mobile wireless broadband service? To answer this question, several dimensions of data were necessary for every location within the United States. The following section briefly discusses how this data was generated.

To study the cost of ubiquitous mobile broadband deployment, **two fundamental methodological definitions** had to be addressed:

1. **The goal of "ubiquitous mobile broadband service" had to be defined.** For the purpose of this analysis, ubiquitous broadband was defined in terms of two different groupings of mobile broadband technology. First, this study analyzes mobile broadband services powered by EVDO and HSPA technologies. Second, this study analyzes next generation OFDM technologies, specifically, LTE and WiMAX.

   - **"Dual" or "full" access.** For each of these groupings, **"ubiquitous dual service"** is defined as the ability to receive both predominant types service at all studied locations. In other words, ubiquitous "dual" next generation OFDM mobile broadband service means the ability to receive mobile wireless broadband service in the technology evolution from both LTE and WiMAX.
     - Within each grouping, if an area can now only receive one class of broadband technology, it was categorized as **"underserved"** and the network was augmented from existing infrastructure to allow the support of both technologies.
     - Again, within each grouping, if the area had neither technology service, the area was categorized as **"unserved"** and the network was augmented with both technologies (and possibly a tower) to support the defined level of service.
   - **"Single" technology access.** In analyzing next generation OFDM mobile broadband technologies, this study also includes an estimate of the costs to deploy a "single" next generation OFDM technology across the country. That is, the study estimates the cost to deploy either LTE or WiMAX, depending on which would require the least investment to augment to full ubiuity. This approach has the drawback of not providing seamless ubiquitous service for a consumer of either given technology; nevertheless, CTIA has included this scenario for the reader's consideration.

2. **The geographic scope of coverage had to be defined.** In the case of a wireless network this is a particularly complicated question. Because mobility is a fundamental characteristic of wireless coverage we felt it was important to both identify where population resides as well as how that population could move (e.g., roads). In other words, some combination of populated areas and paths for movement were necessary coverage targets for the ubiquitous wireless networks. We felt that road paths would capture both attributes: populated areas and paths for movement. As such, our target for coverage is road paths.[4]

[4] The reader is cautioned to not infer that this coverage guarantees a specific quality of service at any particular geographic point. In other words, there is no guarantee of uniform in building or in car standard with this definition. The mobile wireless coverage used in this study does not assume that signal propagation is spread perfectly or even uniformly throughout the covered area. That is, the networks in the covered areas are continually optimized and improved for capacity growth by the carriers who own and manage them.

Methodology Steps

Once "ubiquitous service" was defined and the geographic scope of coverage was established, a number of processes were developed in order to estimate investment. Ultimately, six technical steps ranging from geospatial to cost analysis were used:

1. **Coverage Data Analysis** - Data regarding current wireless deployment for various mobile broadband technology types was identified, filtered and combined with other data sources. Along with the coverage pattern, the technology providing service was evaluated.

2. **Technology Isolation** - Those areas served by each of the wireless technologies were isolated.

3. **Asset Data Analysis** - Existing wireless assets (tower locations) were estimated, filtered and categorized in terms of the existing broadband coverage patterns and network protocols. These towers were then overlaid with the wireless coverage areas.

4. **Road and Population Analysis** - Using the coverage and asset information, the basic requirements for a ubiquitous network could then be estimated using road paths as the coverage target for network build out and estimated coverage areas as the unit of analysis.

5. **Coverage Analysis** - The entire U.S. was divided into areas approximating the area that could be served by a single tower (a polygon shape serving area or 'Study Cell', which will be defined later in this paper). These Study Cells were superimposed over the coverage and asset data. Those Study Cells without any roads were dropped from any further analysis as they did not meet the scope of coverage criteria. It was assumed that new technology was needed in each of the remaining Study Cells (those without any coverage or fractional coverage), providing an estimated count of new technology investment and/or fractional sites needed to provide the desired service coverage. In those Study Cells with some existing coverage by an earlier generation technology (e.g. first generation, second generation, or third generation) the assumption was made that existing towers (or portions thereof) would be located within the Study Cell and would require augmentation.

6. **Investment Development** - Given the count of new technology investment sites and the count of towers requiring augmentation, both from the previous step, the investment required to deploy the mobile broadband assets was developed.

The assumptions included in our methodology present good high-level estimates of populations, roads, and total investment necessary to build-out meaningful mobile broadband service via EVDO and HSPA technologies and next generation OFDM mobile wireless broadband capabilities via LTE and WiMAX technologies. This study is not an attempt at creating the actual final cost, the precise tower count or the bill of materials, to deploy mobile broadband services in any one particular area.

Comparison

2008 Study

As previously noted, CTIA–The Wireless Association® has commissioned CostQuest Associates for a *second time.* The first iteration of this study was conducted by CostQuest Associates in 2008 – to study coverage and potential deployment costs of third generation mobile broadband. The goals were essentially the same - to conduct an analysis regarding ubiquitous mobility in the United States in order to a) identify areas and population not served by mobile broadband technologies, and b) estimate the up-front deployment costs to build mobile broadband networks to unserved and underserved areas. While the goals are the same for this latest version of the study, the technologies deployed by the wireless industry have changed (most notably through an increasing focus on the deployment of OFDM technologies, such as LTE and WiMAX) and our methods have been improved. Given the dynamics of the wireless industry today, CostQuest Associates has taken into account several appropriate external/internal design factors with regards to the conceptualization of this latest version of the study, which differ from that of its predecessor.

Since conducting the first iteration of this study in 2008, along with the improved coverage since 2008 there have been numerous technological and infrastructure design advancements which have aided in altering benchmarks industry-wide. Relatively significant changes in market demand have consequently transformed infrastructure and equipment pricing, effecting overall costs. Improvements in geo-spatial applications have helped to make coverage identification much more accurate. And new and more innovative methods of streamlining and optimizing networks have also been developed further adding to the complexity of tracking the ubiquitous coverage (both physically and financially) of an ever changing mobility ecosystem. We find that these factors are at least partially, if not entirely, attributable for any variances in metrics which may occur when compared to a mere straight forward update of the previous report. The changes implemented are justified in the more accurate and granular report results displayed throughout the report.

Coverage Data Analysis

Coverage Basis Determination

In order to identify uncovered or unserved/underseved areas within the U.S., the study first identified the areas currently *covered* by a mobile wireless signal.

As a result of the complexities inherent in carrier coverage maps and in obtaining standard maps from each carrier, we elected to use a commercial coverage database which has been introduced in several regulatory proceedings.[5] For this study, American Roamer[6] provided coverage data for wireless carriers. The carriers included in this study represent 100% of the wireless market share[7] and cover all 50 states, and the District of Columbia. Coverage for mobile broadband services was derived from American Roamer's Coverage Right Advanced Services (2/2011).

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[5] See uses including http://www.psc.state.fl.us/utilities/telecomm/ETCWorkshop/Alltel.pdf - Showing multiple carrier coverage in Montana and South Dakota, see also Re: In the matter of the Federal-State Joint Board on Long-Term High-Cost Universal Service Reform, WC Docket 05-337, and CC Docket 96-45 (http://fjallfoss.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6519534113)

[6] http://www.americanroamer.com/ - 5909 Shelby Oaks Drive, Suite 105 – Memphis, TN 38134

Technology Isolation

Coverage Protocol and Generation Scenarios

Many wireless networks operate in the United States. Each operator has deployed its network according to its choice of technology, spectrum availability, and coverage objectives. As a result there is mosaic of different services available in different areas. This study has identified specific coverage conditions for these mobile broadband technologies:

- EvDO
- GSM HSPA
- GSM HSPA+
- LTE
- WiMAX

Within both groupings of technologies (*i.e.*, EVDO/HSPA technologies and LTE/WiMAX technologies), there is more than one platform available to consumers. Given that these platforms are not interoperable, coverage by both types of networks within a grouping will be necessary in order for all consumers to retain coverage in all areas.[8] Figure 1 below shows the evolution of technology protocols and research standards used for mobile broadband technologies.

[8] For example, consumers using GSM equipment are not able to access CDMA networks just as consumers with CDMA equipment cannot access GSM networks with that equipment. Currently, there is no user equipment in the market that provides interoperability between LTE and WiMAX networks.

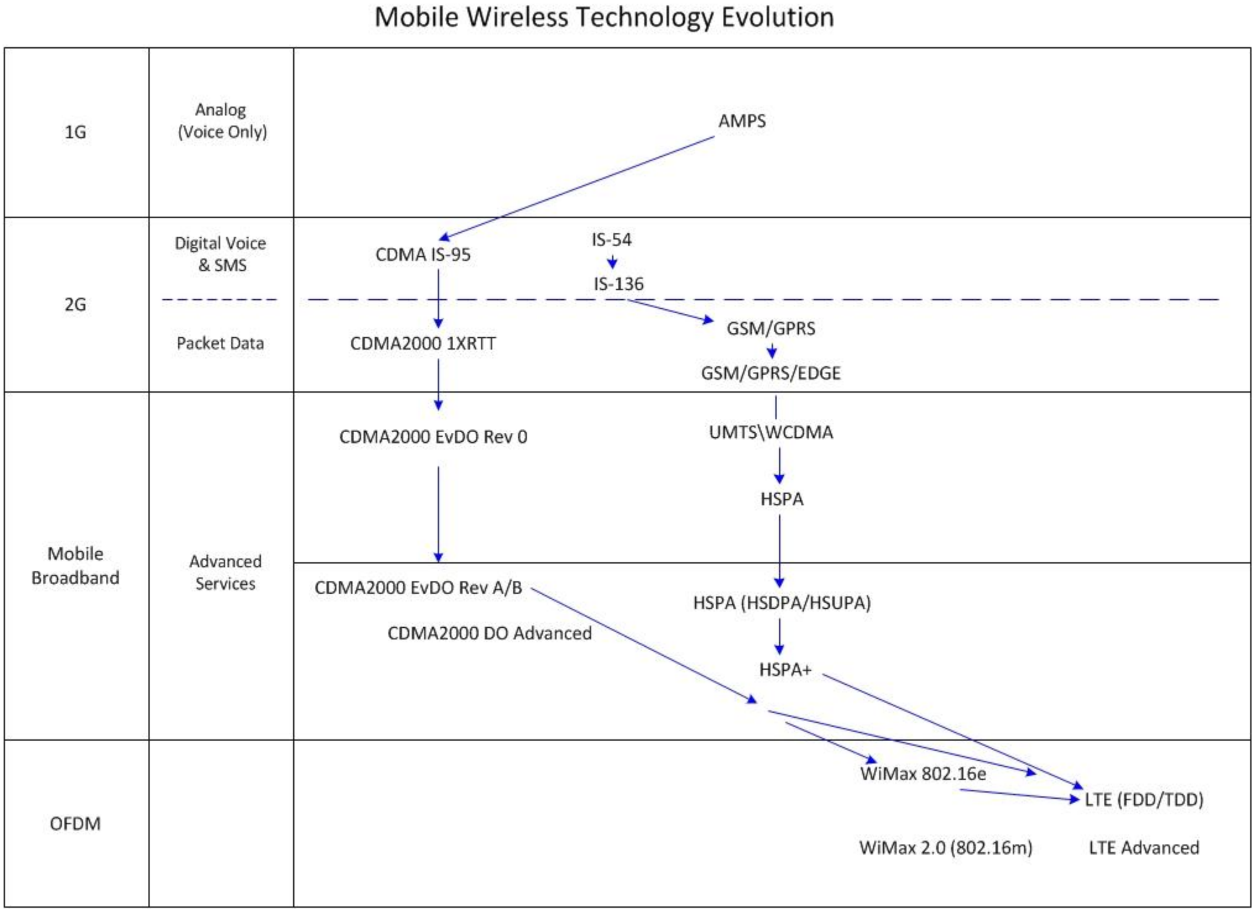

Figure 1: Mobile Wireless Technology Evolution

Nationwide Build Out of Mobile Broadband via EVDO and HPSA Technologies and Next Generation OFDM Mobile Broadband via LTE and WiMAX Technologies

As noted above, the study estimates the cost of building out the two predominant mobile broadband platforms within each grouping (*i.e.*, EVDO/HSPA technologies and LTE/WiMAX technologies) to cover each eligible road segment in the U.S. In Figure 2 below, we show a sample of the coverage of both 1) mobile broadband via EVDO and HSPA technologies, and 2) next generation OFDM mobile broadband via LTE and WiMAX technologies as of the beginning of 2011. Next generation OFDM deployment was further classed into areas with "dual" access (i.e., an LTE provider and a WiMAX provider) or only a single provider. Such "single" OFDM mobile broadband access is also shown in the sample coverage map at Figure 6, below.

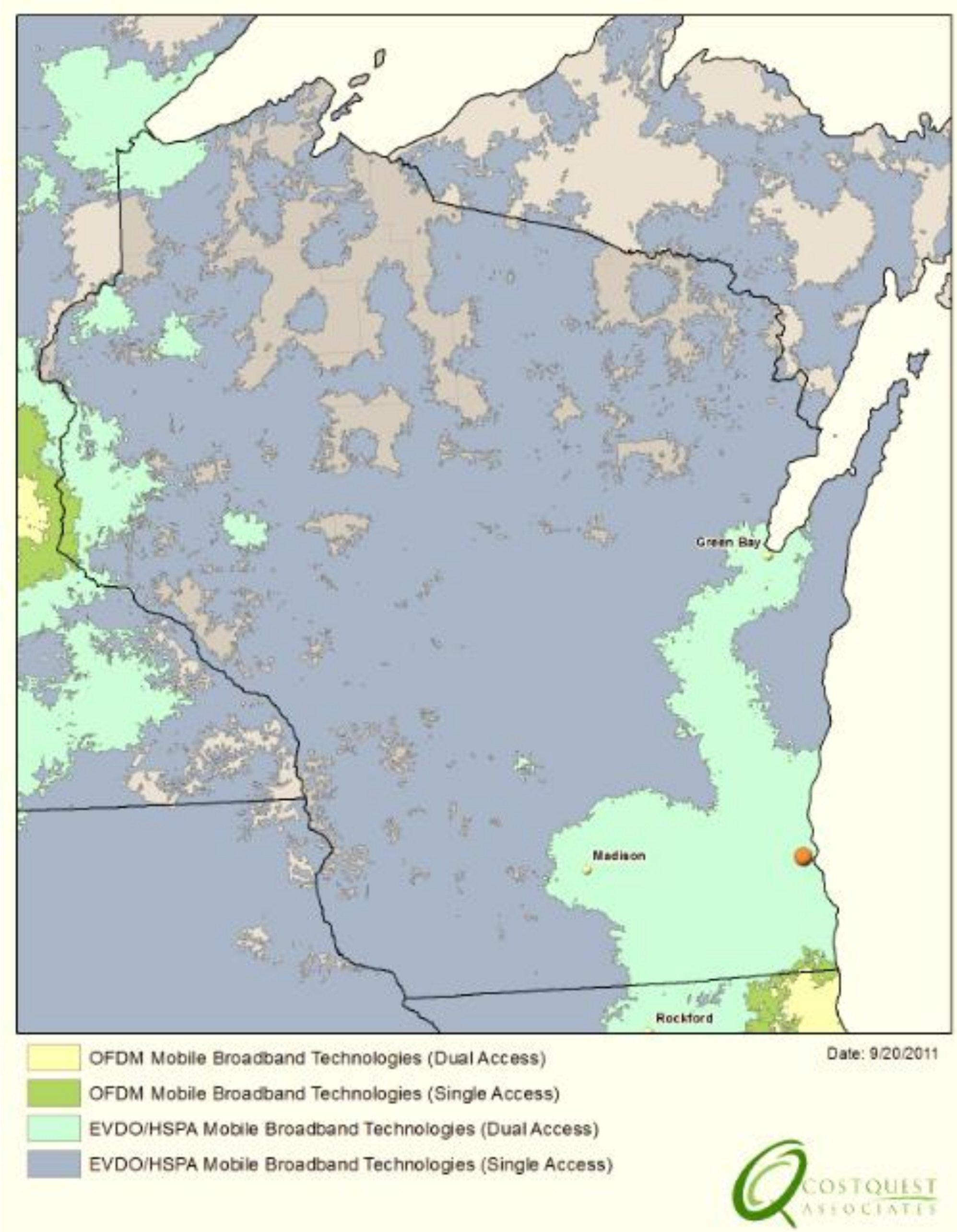

Figure 2: Sample Mobile Broadband Coverage Map (WI)

For those areas only receiving voice services, the study augments each Study Cell with appropriate investment to provide ubiquitous mobile broadband coverage of either EVDO/HSPA mobile broadband technologies or OFDM mobile broadband technologies, depending on which scenarios was being run. For the "dual" or "full" access scenario, the study augments each Study Cell with appropriate investment to provide ubiquitous access to both technologies within a grouping (*i.e.*, both EVDO and HSPA technologies, or both LTE and WiMAX technologies). For the "single" access scenario, the study augments each Study Cell with appropriate investment to provide ubiquitous access to only one next generation OFDM mobile broadband technology (*i.e.*, either LTE or WiMAX), depending on which would require the least investment to augment for full ubiquity.

For those areas currently with no wireless service, the study augments each serving area with appropriate investment to build towers, antennas and a typical portion of microwave backhaul to provide the desired level of mobile broadband coverage for each of the scenarios described above.

Finally, in those areas where only one technology is deployed, the study augments these serving areas with the appropriate investment to provide dual access to both technologies within the grouping (e.g., adding LTE service where only WiMAX is available; or adding EVDO service where only an HSPA technology is available). Of course, for the "single" access OFDM mobile broadband scenario, no additional investment was required where one OFDM mobile broadband technology was present.

Asset Data Analysis

Towers and Sites

Coverage was used to determine tower availability. For example, a Study Cell with 100% coverage was assumed to contain a tower that could be used for augmentation.[9] For Study Cells with partial coverage that are determined to be "underserved", the logic assumed only a fractional unit of tower would be required. While not exact for a specific individual Study Cell, this "melding" approach provides a good estimate over a larger geographic area.

Road and Population Analysis

Coverage Demand Identification

Population

While not a direct unit of analysis for the development of augmentation costs, population was studied to determine the counts of potential subscribers who are in "underserved" or "unserved" areas. Population data were derived from Geolytics and GeoResults 2009 estimates. Population was dispersed to randomly place housing units within census blocks. To this, business locations were added via random disbursement within the census block. These random placed points, with population counts, were then rolled up into the corresponding Study Cell that contained the point.

RoadsTIGER 2009 roads were used as targets for routes for mobility. Eligible road types were determined based upon the MAF/TIGER Feature Classification Code (MTFCC). Vehicular trails, Ramps, Stairways, Service Roads, Bike Paths, Trails, Bridal Paths, and Road Medians were excluded from the study.[10] Thus, this study presents estimates to provide mobile broadband coverage to roads where most users might reasonably be expected to travel, rather than blanketing the entire country with coverage

[9] The assumption that an existing tower would be available to augment is based on the widespread industry practice of collocating multiple technologies and multiple carriers on tower locations which are often owned by commercial tower operators. Augmenting a site requires less capital investment (particularly site preparation and tower erection) but also results in additional operational expense (e.g., lease cost).

[10] If any of these additional roads and trails were included in the analysis, there would be considerably more road miles to cover.

Identifying Features of Interest

For this study isolating the population, roads, tower assets and extent of coverage by technology was necessary. This was accomplished by using a Geographic Information System (GIS).[11]

A geo-processing model was used to layer the various coverage layers with our pre-defined tower serving areas to identify the areas of the tower serving area served by a mobile broadband technology of each respective grouping and various combinations, which in turn was used to derive various ratios of coverage. These ratios were then applied to the housing units, business locations, population, and road footage within a Study Cell to estimate the coverage of each respective technology.

Coverage Analysis

Coverage

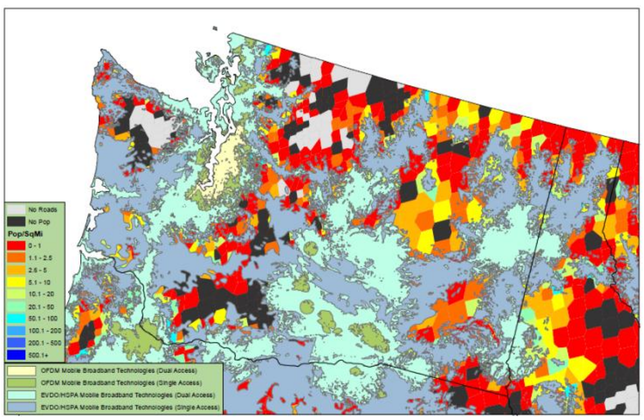

Figure 3

As described in the Assumptions and Calculations discussion at the end of this section, a polygon shaped serving area, referred to as a Study Cell, was used to represent the reach of a tower site in "ubiquitously served," "underserved" and "unserved" areas. [12] Once the percentage of area served by each network technology were developed, they were then passed on to the calculation engine to determine build out requirements[13].

The percentage of coverage by each network protocol within a Study Cell was then used to determine whether mobile broadband augmentation would be required[14] and the type of augmentation. Polygon areas with no road feet covered by an existing mobile broadband or voice technology required a full site deployment (e.g., tower, antenna, microwave, etc.). In these areas, a single site was assumed sufficient to serve the entire polygon area.

Polygon areas covered by only voice based technologies (i.e., no mobile broadband deployment) were identified as areas that required upgrades to mobile broadband technologies. In contrast to the unserved areas, these polygon areas only required upgrade equipment – augmentation - rather than the equipment needed to fit out a full tower site. In these areas, it was also assumed that a single tower site could be deployed with mobile broadband equipment to serve the entire area.

The final types of areas analyzed were those that were partially covered with mobile broadband services. In these cells, a full tower was assumed to be required when the percentage of the cell covered by all technologies

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[11] ESRI, ArcView

[12] We assumed that in lower density areas, distance from the tower was the key limitation on design. As density increases (i.e., users), both traffic and distance can limit the service area of a tower.

[13] There were approximately 82,000 Study Cells in the study.

[14] For purposes of the study, augmentation was triggered when more than ½ of a person or 2 mile of roads within a polygon area was found to be uncovered.

was below 75%. For cells with coverage above 75%, a fraction of a tower was assumed to be required.[15] Similar logic was used for developing the electronic augmentation investments. The only difference is that the coverage of the specific technology was only considered.

By-and-large, "ubiquitously served" areas are typically located in counties with population density greater than 100 people per square mile. To put that into perspective, the FCC has reported that 79% of the U.S. population lives in non-rural counties representing no more than 14% of the geographic area of the United States.[16]

In our analysis of next generation OFDM service coverage, for those areas already served by both an LTE and WiMAX service provider, no additional investment was needed. As of the end of 2010, ubiquitous OFDM mobile broadband service is estimated to reach 29% of the population but only 4.6% of the populated area of the United States.

Investment Development

As mentioned in the introduction, this study was commissioned to identify only the initial capital investment of deploying ubiquitous wireless broadband coverage across the nation. This study also did not attempt to include the costs of spectrum, which are often significant.

The study develops investment requirements for the following scenarios:

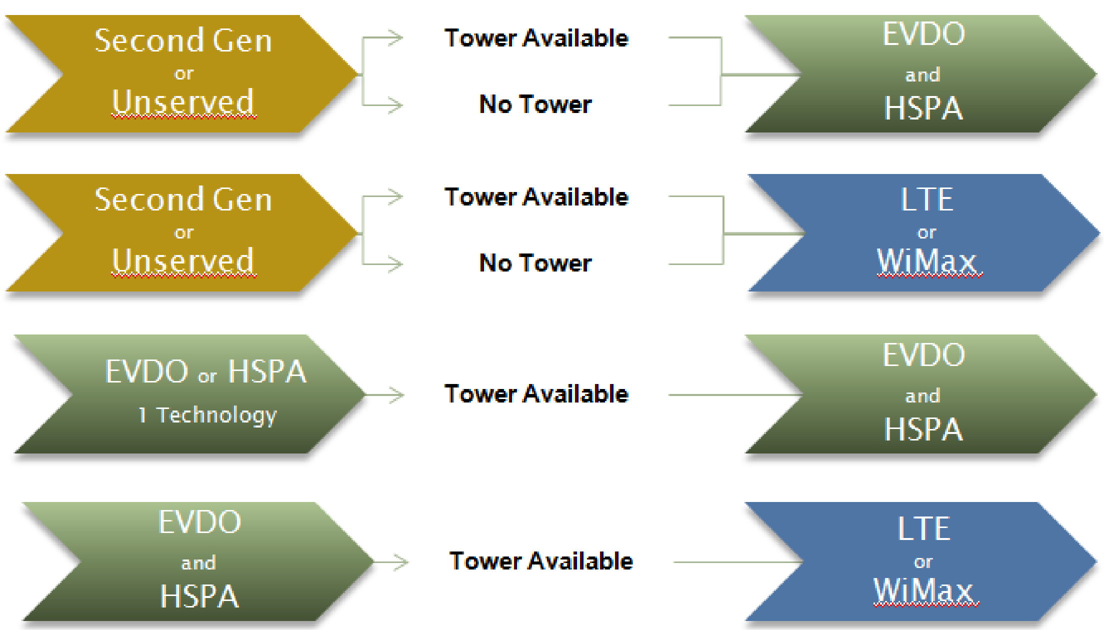

Figure 4

[15] While it is understood that fractional towers are not installed, given the disconnect between the idealized HTCell polygons and the actual service polygons, the fractional approach provides a reasonable estimate of tower and augmentation investment over a large geographic area.
[16] See Annual Report and Analysis on the Competitive Market Conditions With Respect to Commercial Mobile Services, WT Docket No. 07-71, FCC 08-28 (rel. Feb. 4, 2008), at para 37.

Direct and Indirect Capital Investment Estimates

In our analysis of mobile broadband via EVDO and HSPA technologies, for those areas already fully served by both CDMA (EvDO) and GSM (HSPA) based technologies, no additional investment was needed.

For those areas that are currently unserved or partially served by any wireless service, the Study Cell analysis provided the total counts of tower sites and partial sites that need to be deployed. This count of tower sites was multiplied by the costs for a full site deployment for both technologies, except in the case of the "single" OFDM mobile broadband scenario in which the analysis used the cost for deployment of the OFDM technology which required less investment to augment to full ubiquity. Site deployment cost includes the base station, tower, antenna, site acquisition, microwave backhaul, etc.

For those areas where a tower exists but service coverage has to be augmented to provide "dual" coverage, the Study Cell analysis provides the count of towers and partial sites where the technologies need to be deployed. Based on the deployment requirements, the tower count was then multiplied by the required augmentation costs, which include all upgrade components required at the site.

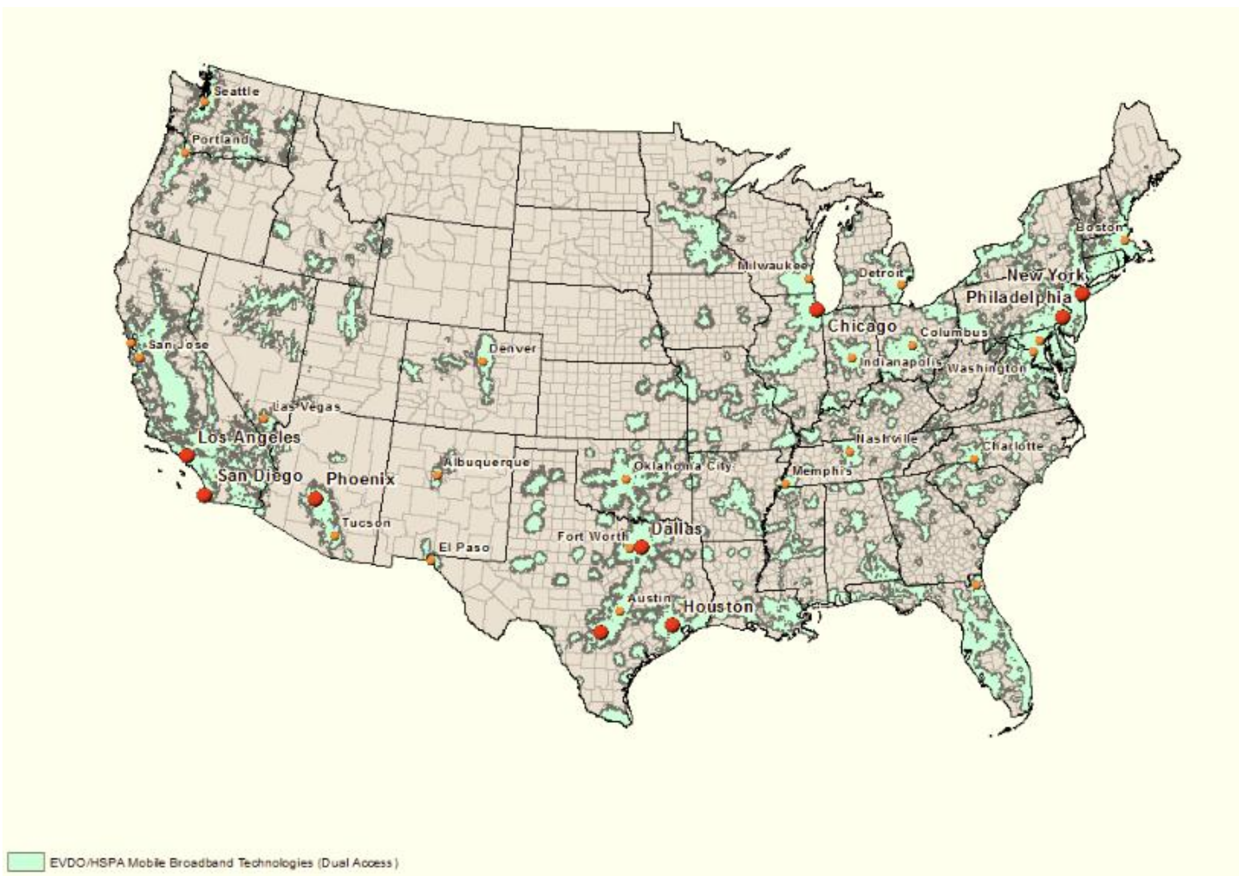

Figure 5: Areas currently served by Mobile Broadband via EVDO/HSPA Technologies.

Figure 6: Areas currently served by OFDM Mobile Broadband Technologies.

Radio Access Network (RAN) costs (i.e., Study Cell site base station or "Node B" costs) used in the study is based on cost data referenced by the FCC[17].

Cost estimates were also included to account for incremental core network capital required to support additional and/or upgraded RAN costs. These estimates were included in the study by multiplying the tower and augmentation costs by a factor. These core network investments account for incremental capacity demands on network routing, control, and support fixtures. The factor applied only represents the additional capital investment related to the initial build-out for unserved and underserved areas.

Spectrum costs were not included in this study. The substantial costs associated with acquiring spectrum could be considered for further studies.

Assumptions and Inputs

Engineering Parameters

Given that this is an exercise in determining a national cost estimate to provide ubiquitous mobile wireless broadband coverage as opposed to specific site-by-site engineering, standard GSM/HSPA, CDMA/EvDO, and OFDM deployment parameters, engineering, and costs were considered sufficient.

[17] FCC Staff Technical Paper "Mobile Broadband: The Benefits of Additional Spectrum", October 2010. See Section VI(c) pps 24-25.

If site-specific costs are of interest, details related to network deployment at each site, such as tower height, topography, frequency and handsets used would be required.

Signal Propagation Radius

Study Cells

To develop the Study Cells used in the study, we started the process with HTCells (hexagonal tessellation cells). The use of HTCells is symbolic of a three sector HTCells site and the hexagonal shape provides a method to simulate 100% coverage. The following diagram depicts a hypothetical overlay of -HT Cells in three Census areas deemed to be unserved by existing coverage. In this example, the unserved area could be covered by thirteen -HTCells.

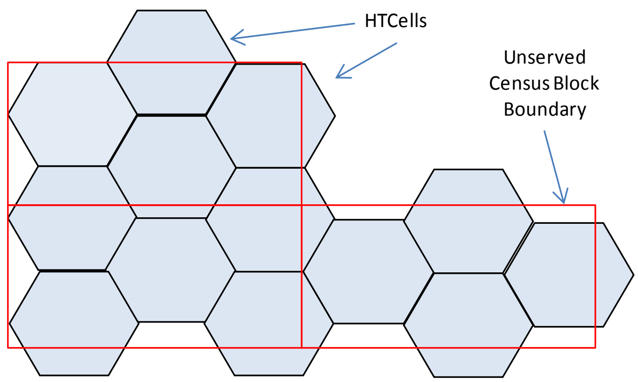

Figure 8

For purposes of this model, each HTCell is assumed to house at least one antenna site. In the case where an existing site structure is used to place a new site antenna, the actual location of that tower is used in the model. In the case of a 'greenfield' build, the site is assumed to be at the center point of the HTCell.

The tower set that the model incorporated was created from a range of HTCell sizes from as small as ½ mile to 10 miles. The criteria for HTCell sizing included population density and terrain variation. Census tracts were used as the base geography for this process, but were split further into block groups in high density areas. As HTCells of different sizes are placed together, demand locations are routed to their nearest tower to create the service footprint of each tower, as shown below in Figure 8, which we refer to as a Study Cell

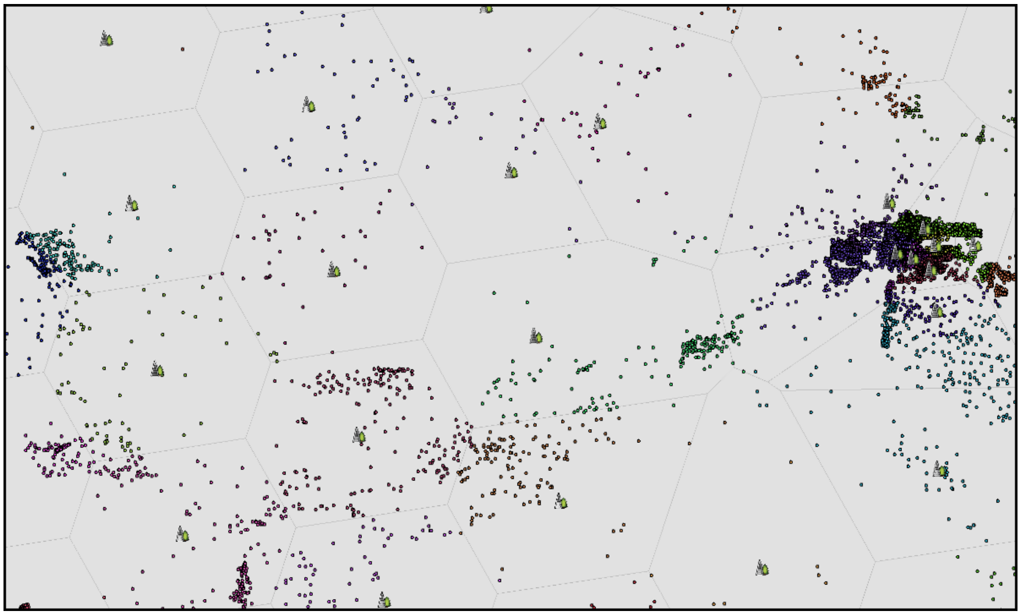

Figure 9: Demand locations within Study Cells

In reality a provider would have to deal with tower sites where estimated demand exceeds the capacity of a single site by splitting the Study Cell into multiple units that results in the addition of one or more sites to meet the overall capacity demanded within the Study Cell area. However, for this study, we were interested in a single provider of each technology building out their footprint. As such, Study Cell splitting was not used. If Study Cell splitting were in fact used and/or multiple technology providers, the total estimated build out would increase.

It is important to note that variances in accuracy that occur at the Study Cell will tend to be mitigated as the model is applied to larger aggregations of unserved area Census Blocks (e.g., into market areas).

Other Engineering Parameters

- Maximum customers per site/tower were assumed to fall between 2,000 and 2,500 customers based on 60 mErlang per subscriber.
- Maximum propagation radius for any deployment would be no more than 22 miles. However, given our grid Study Cells and their assumed signal radius, no main road was greater than roughly 6 miles from a tower.
- The analysis assumes the use of existing, deployed spectrum including Cellular, PCS, SMR, and AWS-1 bands.[18]

Cost Development Assumptions

Cost estimates for direct (e.g., tower, site electronics, etc.) capital investment were based on cost data referenced by the FCC[19] in the recent mobile report. There estimates were $300,000 for a full site build and $130,000 for an augmentation at an existing site. Other network (e.g., mobility management) incremental capital investment were derived from requests to providers and from CostQuest's work in the wireless industry and are meant to serve as a broad average for deployment of new network equipment.

Tower/Site Cost Estimates

Full site deployment costs, which includes the base station, tower, antennas, cabling, site acquisition, site development, microwave backhaul, etc., are estimated to be $300,000 per site.[20]

For those locations where a tower exists but service is augmented, augmentation costs including all upgrade components required at the site are estimated to be $130,000.

To improve the location accuracy of the estimated build out costs, a regional cost adjustment was applied that varied cost at the 3 digit zip code level. This regional cost adjustment was pulled from RSMeans[21].

Spectrum

Spectrum costs were **not** included in this study. The substantial costs associated with acquiring spectrum could be considered for further studies.

Loadings

Based on the assumption that coverage in unserved and underserved areas would be provided by a network operator with existing core network operations, an estimate was made to account for the incremental additional capital necessary to support an expanded core network sufficient to address incremental demand. This augment to the core network includes switching/routing, service authentication, service gateways, support equipment, etc., and is estimated to be 5% of the direct site investment. This represents only the secondary capital investment related to the initial build-out for unserved and underserved areas.

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[18] Since various spectrum bands are assigned to multiple carriers in each potential service area, the model does not attempt to mirror the utilization of a specific spectrum band. Rather, the model uses an average anticipated performance across multiple bands. It is certainly the case that utilization of different spectrum bands and different channel allocations in a similar service area will result in differing levels of network performance and/or infrastructure requirement.

[19] FCC Staff Technical Paper "Mobile Broadband: The Benefits of Additional Spectrum", October 2010. See Section VI(c) pps 24-25.

[20] ibid

[21] RSMeans is an outside third party expert that publishes yearly outside plant construction costs. For this effort, we used the 2011 RSMeans Combined Locational Adjustment for Material & Labor.

In addition to the Core/Secondary loadings, additional loadings were applied to capture: Spares, the Edge Core network, interest during construction, capitalized labor and sales tax. In total, these loadings were 35%.

Up Front Capital Study Limitation

This study does not estimate costs related to maintaining the networks or providing service. Additional analysis would need to be performed to identify capital and operating costs related to maintenance, optimization (coverage and capacity adjustments for changing market conditions), and the general service and administrative costs associated with such networks.

Ubiquitous Wireless Broadband Study Results

Findings

Next Generation OFDM Mobile Broadband Services
(LTE and WiMAX Technologies)

1. Approximately **165 Million U.S. residents** currently do not have access to any form of next generation OFDM mobile broadband service (LTE or WiMAX) at their primary place of residence. About **225 Million** do not have access to both technologies of next generation OFDM mobile broadband.

2. We estimate that approximately **90% of road miles** in the United States do not have access to any next generation OFDM mobile broadband services. Approximately 95% of road miles do not have access to both technologies of next generation OFDM mobile broadband.

3. The estimated minimum investment needed to build out infrastructure to facilitate the two technologies of next generation OFDM mobile broadband service ubiquitously is approximately **$21 billion**. The estimated minimum investment needed to build out infrastructure to facilitate only one next generation OFDM technology is approximately $10 billion.

4. In order to achieve "full" next generation OFDM mobile broadband coverage, approximately **6,558 new towers** will need to be constructed and **115,000 existing towers** will need to be augmented with LTE and WiMAX technologies.

5. Nearly a **third of the investment** necessary for bringing next generation OFDM broadband ubiquity to the U.S. is for **augmentation** of existing site locations.

Mobile Broadband Services via EVDO and HSPA Technologies

1. Approximately **54 Million U.S. residents** currently do not have full access to *dual* mobile broadband service via EVDO and HSPA technologies at their primary place of residence.

2. We estimate that approximately **62% of road miles** in the United States do not have full access to dual mobile broadband services via EVDO and HSPA technologies.

3. The estimated minimum investment needed to build out infrastructure to facilitate the two technologies of mobile broadband service ubiquitously is approximately **$7.8 billion**.

Coverage and Required Investment by Generation

Population and Roads

Ubiquitous Dual Access to Mobile Broadband via EVDO and HSPA Technologies

Based on our study, **more than 53 million U.S. residents lack access to *dual*** mobile broadband services via EVDO and HSPA technologies at their place of residence. **Approximately 4.3 million road miles lack such coverage.** The following table shows population and roads unserved by dual EVDO/HSPA mobile broadband networks, by state.

State	Unserved Roads	Percent Roads Unserved	Unserved Pops	Percent Pops Unserved
Alabama	86,613	65%	1,850,185	39%
Alaska	25,154	87%	420,852	59%
Arizona	124,466	71%	782,708	11%
Arkansas	85,977	69%	1,184,950	41%
California	124,495	33%	1,199,333	3%
Colorado	111,930	75%	711,688	14%
Connecticut	1,022	4%	85,523	2%
Delaware	851	9%	45,854	5%
District of Columbia	0	0%	0	0%
Florida	50,837	25%	1,258,511	6%
Georgia	120,892	67%	2,463,912	24%
Hawaii	2,891	25%	169,600	13%
Idaho	102,246	79%	415,354	26%
Illinois	83,702	47%	1,641,149	12%
Indiana	64,183	52%	1,644,639	25%
Iowa	121,477	91%	1,866,117	62%
Kansas	147,688	85%	1,007,612	35%
Kentucky	66,252	63%	1,507,490	34%
Louisiana	57,575	57%	872,761	20%
Maine	44,313	86%	828,302	62%
Maryland	2,775	5%	100,419	2%
Massachusetts	4,395	9%	165,690	3%
Michigan	112,040	65%	2,453,303	24%
Minnesota	107,347	63%	1,080,776	20%
Mississippi	78,804	68%	1,261,387	43%
Missouri	120,510	63%	1,343,382	22%
Montana	156,700	100%	976,709	100%
Nebraska	122,331	94%	861,134	47%
Nevada	72,274	70%	158,027	5%
New Hampshire	14,850	59%	376,342	28%
New Jersey	2,317	5%	160,021	2%
New Mexico	170,533	92%	873,576	42%
New York	55,513	38%	1,518,253	8%
North Carolina	104,875	64%	3,331,651	34%
North Dakota	134,025	100%	635,246	100%
Ohio	72,191	47%	2,330,346	20%
Oklahoma	90,943	51%	619,770	17%
Oregon	170,446	81%	559,883	14%
Pennsylvania	79,389	44%	2,025,017	16%
Rhode Island	390	5%	25,153	2%
South Carolina	58,791	59%	1,361,443	29%
South Dakota	90,871	100%	793,977	100%
Tennessee	80,148	63%	1,988,561	31%
Texas	414,660	62%	2,577,657	10%
Utah	95,632	80%	289,687	10%
Vermont	14,417	69%	293,639	47%
Virginia	75,399	48%	1,519,936	19%
Washington	79,611	55%	555,176	8%
West Virginia	53,696	73%	907,208	51%
Wisconsin	101,872	74%	2,090,192	36%
Wyoming	124,211	99%	514,140	97%

4G Network Access

Ubiquitous Dual Access to Mobile Broadband via OFDM Technologies

This study shows that **roughly 225 million U.S. residents lack access to both next generation OFDM mobile broadband services** at their place of residence. Approximately **6.5 million road miles lack such coverage**. More than **165 million residents lack access to *either* technology of OFDM mobile broadband service**. The following table shows population and roads unserved by dual OFDM networks, by state.

State	Unserved Roads	Percent Roads Unserved	Unserved Pops	Percent Pops Unserved
Alabama	132,495	100%	4,737,320	100%
Alaska	28,692	100%	716,638	100%
Arizona	176,324	100%	7,134,278	100%
Arkansas	124,885	100%	2,911,722	100%
California	332,736	88%	21,551,939	56%
Colorado	143,417	96%	3,486,385	67%
Connecticut	27,313	99%	3,431,635	97%
Delaware	8,017	86%	610,955	67%
District of Columbia	100	8%	33,726	5%
Florida	168,745	84%	11,836,903	60%
Georgia	165,480	91%	6,466,027	62%
Hawaii	11,709	100%	1,340,874	100%
Idaho	129,719	100%	1,611,604	100%
Illinois	150,354	85%	6,239,283	47%
Indiana	122,209	100%	6,415,691	99%
Iowa	134,017	100%	3,018,033	100%
Kansas	173,340	100%	2,838,407	100%
Kentucky	103,790	99%	4,212,156	95%
Louisiana	101,367	100%	4,410,728	100%
Maine	51,720	100%	1,345,291	100%
Maryland	43,308	77%	2,790,464	47%
Massachusetts	39,561	79%	3,646,716	56%
Michigan	171,686	100%	10,245,515	100%
Minnesota	161,262	94%	3,163,295	59%
Mississippi	116,591	100%	2,945,155	100%
Missouri	182,547	95%	4,291,151	71%
Montana	156,845	100%	977,283	100%
Nebraska	129,705	100%	1,836,598	100%
Nevada	96,629	94%	895,903	30%
New Hampshire	25,120	100%	1,333,632	99%
New Jersey	38,511	75%	4,547,183	51%
New Mexico	184,501	100%	2,071,457	100%
New York	134,785	92%	10,012,003	51%
North Carolina	157,154	96%	8,523,937	88%
North Dakota	134,025	100%	635,246	100%
Ohio	139,160	91%	8,259,890	71%
Oklahoma	177,499	100%	3,728,161	100%
Oregon	211,229	100%	3,944,685	100%
Pennsylvania	163,129	91%	8,605,944	69%
Rhode Island	5,833	81%	612,975	59%
South Carolina	99,571	100%	4,693,265	100%
South Dakota	90,871	100%	793,977	100%
Tennessee	121,460	95%	5,339,463	83%
Texas	619,031	92%	14,141,120	54%
Utah	119,336	100%	2,966,843	100%
Vermont	20,982	100%	627,241	100%
Virginia	154,684	98%	7,031,826	86%
Washington	134,245	92%	4,371,315	64%
West Virginia	73,208	100%	1,794,404	100%
Wisconsin	137,868	100%	5,771,954	100%
Wyoming	124,996	100%	532,023	100%

Ubiquitous Single Access to Mobile Broadband via OFDM Technologies

State	Unserved Roads	Percent Roads Unserved	Unserved Pops	Percent Pops Unserved
Alabama	132,492	100%	4,737,263	100%
Alaska	28,692	100%	716,638	100%
Arizona	157,399	89%	2,852,086	40%
Arkansas	124,885	100%	2,911,722	100%
California	292,667	77%	11,949,201	31%
Colorado	136,770	91%	2,380,074	46%
Connecticut	18,512	67%	1,571,134	44%
Delaware	7,307	78%	475,625	52%
District of Columbia	0	0%	0	0%
Florida	143,292	71%	8,388,164	42%
Georgia	156,110	86%	5,383,906	51%
Hawaii	8,787	75%	464,012	35%
Idaho	125,200	97%	1,031,377	64%
Illinois	136,569	77%	4,242,825	32%
Indiana	120,344	98%	6,129,409	94%
Iowa	134,017	100%	3,018,033	100%
Kansas	169,488	98%	2,174,917	77%
Kentucky	102,902	98%	4,088,874	93%
Louisiana	94,641	93%	3,467,623	79%
Maine	51,720	100%	1,345,291	100%
Maryland	38,059	68%	1,976,812	33%
Massachusetts	34,732	69%	2,894,617	44%
Michigan	152,622	89%	6,002,989	59%
Minnesota	150,460	88%	2,335,759	43%
Mississippi	116,586	100%	2,945,137	100%
Missouri	174,280	91%	3,288,624	55%
Montana	156,845	100%	977,283	100%
Nebraska	129,705	100%	1,836,598	100%
Nevada	96,293	94%	885,158	29%
New Hampshire	25,043	99%	1,324,455	99%
New Jersey	30,637	60%	3,166,229	35%
New Mexico	184,501	100%	2,071,457	100%
New York	120,591	83%	7,372,705	38%
North Carolina	135,758	83%	5,678,178	59%
North Dakota	134,025	100%	635,246	100%
Ohio	122,617	80%	6,211,798	54%
Oklahoma	153,620	87%	2,375,292	64%
Oregon	202,422	96%	1,951,467	49%
Pennsylvania	140,390	79%	6,169,239	49%
Rhode Island	4,755	66%	436,937	42%
South Carolina	97,020	97%	4,446,639	95%
South Dakota	90,871	100%	793,977	100%
Tennessee	106,917	84%	4,673,509	73%
Texas	583,408	87%	9,708,531	37%
Utah	111,365	93%	1,027,740	35%
Vermont	20,982	100%	627,241	100%
Virginia	145,749	92%	5,381,920	66%
Washington	122,700	84%	2,721,393	40%
West Virginia	73,169	100%	1,793,870	100%
Wisconsin	137,081	99%	5,711,145	99%
Wyoming	124,996	100%	532,023	100%

Infrastructure and Investment

Ubiquitous Dual Access to Mobile Broadband via EVDO and HSPA Technologies

We estimate that it will require **about $7.8 billion of upfront capital to deploy ubiquitous coverage of dual mobile broadband via EVDO and HSPA technologies** in the U.S. Below is a summary of findings related to the investment estimates:

State	New Towers	Augmented Towers	Total Investment
Alabama	27	560	$ 91,884,097
Alaska	807	1,299	$ 669,734,867
Arizona	262	1,153	$ 279,002,175
Arkansas	28	433	$ 71,270,207
California	744	2,017	$ 726,384,319
Colorado	273	1,245	$ 311,989,432
Connecticut	31	42	$ 20,609,722
Delaware	7	13	$ 5,502,887
District of Columbia	0	0	$ -
Florida	202	481	$ 149,153,282
Georgia	28	666	$ 110,154,152
Hawaii	132	210	$ 109,188,486
Idaho	343	935	$ 285,110,468
Illinois	30	427	$ 88,656,464
Indiana	9	435	$ 74,139,299
Iowa	0	549	$ 83,890,773
Kansas	0	431	$ 66,138,094
Kentucky	31	548	$ 98,948,116
Louisiana	14	401	$ 65,207,678
Maine	75	301	$ 86,267,820
Maryland	20	38	$ 13,009,543
Massachusetts	53	97	$ 40,032,243
Michigan	139	661	$ 162,719,292
Minnesota	45	505	$ 107,251,183
Mississippi	16	400	$ 67,841,995
Missouri	15	460	$ 82,661,517
Montana	416	1,336	$ 371,854,483
Nebraska	20	482	$ 86,133,302
Nevada	356	820	$ 296,007,422
New Hampshire	19	181	$ 41,016,728
New Jersey	45	61	$ 30,430,387
New Mexico	229	1,247	$ 288,236,384
New York	186	730	$ 224,029,802
North Carolina	101	1,010	$ 172,924,568
North Dakota	16	383	$ 63,377,408
Ohio	78	640	$ 138,802,221
Oklahoma	6	323	$ 48,546,511
Oregon	274	1,046	$ 300,810,056
Pennsylvania	79	790	$ 165,879,119
Rhode Island	6	6	$ 3,790,242
South Carolina	28	360	$ 61,455,520
South Dakota	56	448	$ 85,213,148
Tennessee	43	609	$ 104,297,205
Texas	113	1,553	$ 253,893,654
Utah	282	952	$ 245,519,764
Vermont	27	242	$ 55,380,891
Virginia	113	594	$ 132,453,953
Washington	319	1,062	$ 323,392,012
West Virginia	87	464	$ 113,369,741
Wisconsin	72	619	$ 135,965,862
Wyoming	250	920	$ 224,220,710

Ubiquitous Dual Access to Mobile Broadband via OFDM Technologies

We estimate that it will require roughly $21 billion of upfront capital to deploy ubiquitous dual next generation OFDM mobile broadband in the U.S. Below is a summary of findings related to the investment estimates:

State	New Towers	Augmented Towers	Total Investment
Alabama	27	1,932	$ 294,929,173
Alaska	807	1,419	$ 695,571,415
Arizona	262	3,493	$ 649,632,169
Arkansas	28	1,360	$ 204,597,424
California	744	11,406	$ 2,564,953,429
Colorado	273	3,176	$ 632,755,198
Connecticut	31	1,119	$ 216,530,982
Delaware	7	188	$ 38,142,903
District of Columbia	0	0	$ 2,275,196
Florida	202	4,113	$ 723,684,427
Georgia	28	2,290	$ 353,949,104
Hawaii	132	717	$ 216,589,371
Idaho	343	1,697	$ 408,346,561
Illinois	30	2,264	$ 425,388,595
Indiana	9	2,636	$ 435,122,554
Iowa	0	1,585	$ 242,590,527
Kansas	0	1,523	$ 235,879,566
Kentucky	31	1,783	$ 300,849,596
Louisiana	14	1,755	$ 269,056,863
Maine	75	629	$ 145,906,247
Maryland	20	1,117	$ 181,709,206
Massachusetts	53	1,409	$ 278,924,581
Michigan	139	3,479	$ 645,087,380
Minnesota	45	1,466	$ 278,752,315
Mississippi	16	1,225	$ 195,621,250
Missouri	15	1,690	$ 288,098,279
Montana	416	1,939	$ 469,887,039
Nebraska	20	1,338	$ 225,606,335
Nevada	356	1,693	$ 452,377,285
New Hampshire	19	669	$ 129,976,795
New Jersey	45	1,791	$ 345,471,799
New Mexico	229	2,308	$ 459,589,964
New York	186	4,243	$ 932,173,398
North Carolina	101	3,068	$ 461,320,456
North Dakota	16	676	$ 107,802,892
Ohio	78	3,051	$ 545,209,664
Oklahoma	6	1,689	$ 246,300,636
Oregon	274	2,664	$ 594,314,868
Pennsylvania	79	3,546	$ 652,311,630
Rhode Island	6	217	$ 42,145,450
South Carolina	28	1,669	$ 251,299,904
South Dakota	56	808	$ 138,295,091
Tennessee	43	2,276	$ 349,935,119
Texas	113	6,330	$ 929,840,754
Utah	282	2,424	$ 472,857,584
Vermont	27	403	$ 84,707,051
Virginia	113	3,016	$ 512,564,809
Washington	319	2,883	$ 651,975,846
West Virginia	87	890	$ 185,748,898
Wisconsin	72	2,478	$ 461,145,224
Wyoming	250	1,359	$ 290,101,161

Ubiquitous Single Access to Mobile Broadband via OFDM Technologies

State	New Towers	Augmented Towers	Total Investment
Alabama	27	953	$ 150,099,867
Alaska	807	306	$ 459,367,216
Arizona	262	1,189	$ 284,077,547
Arkansas	28	666	$ 104,900,479
California	744	4,287	$ 1,169,844,815
Colorado	273	1,300	$ 320,878,764
Connecticut	31	372	$ 80,653,547
Delaware	7	73	$ 16,793,876
District of Columbia	0	0	$ 0
Florida	202	1,580	$ 323,306,756
Georgia	28	1,014	$ 162,116,012
Hawaii	132	211	$ 109,334,618
Idaho	343	619	$ 231,981,592
Illinois	30	908	$ 176,898,019
Indiana	9	1,282	$ 213,221,034
Iowa	0	792	$ 121,333,564
Kansas	0	676	$ 104,516,845
Kentucky	31	861	$ 151,098,323
Louisiana	14	773	$ 121,107,052
Maine	75	277	$ 81,873,824
Maryland	20	405	$ 70,180,652
Massachusetts	53	588	$ 129,473,906
Michigan	139	1,172	$ 249,228,832
Minnesota	45	618	$ 128,128,884
Mississippi	16	604	$ 99,378,982
Missouri	15	724	$ 126,817,604
Montana	416	762	$ 278,936,522
Nebraska	20	659	$ 114,922,588
Nevada	356	658	$ 265,646,824
New Hampshire	19	324	$ 67,055,942
New Jersey	45	678	$ 142,642,717
New Mexico	229	1,039	$ 254,088,007
New York	186	1,754	$ 431,405,023
North Carolina	101	1,235	$ 204,723,165
North Dakota	16	330	$ 55,438,698
Ohio	78	1,266	$ 243,860,975
Oklahoma	6	672	$ 99,167,871
Oregon	274	989	$ 291,417,576
Pennsylvania	79	1,496	$ 292,474,161
Rhode Island	6	84	$ 17,944,884
South Carolina	28	800	$ 125,298,470
South Dakota	56	376	$ 74,560,949
Tennessee	43	1,060	$ 170,759,267
Texas	113	2,620	$ 405,560,790
Utah	282	868	$ 233,315,262
Vermont	27	188	$ 45,572,023
Virginia	113	1,246	$ 235,219,143
Washington	319	1,109	$ 332,401,554
West Virginia	87	402	$ 102,578,962
Wisconsin	72	1,199	$ 238,126,726

About CostQuest

CostQuest Associates develops solutions related to costs, pricing, business management, and regulatory analysis. CostQuest's recent projects include Broadband Network Modeling, Forward Looking Cost Models, Broadband Mapping, Profitability Analysis, Regulatory Compliance Consultation and Regulatory Advocacy Support. CostQuest Associates worked with the FCC to develop the Cost Model for the National Broadband Plan.

CostQuest is a world-wide leader in Universal Service Fund modeling and policy analysis. CostQuest developed models to support USF with the FCC (US) and for foreign governments including Australia, New Zealand, and Hong Kong. CostQuest Associates has written policy analysis papers on modeling, reverse auctions, 10th circuit issues, and various other USF related issues.